

Ocean Dynamics and Acoustic Variability in East China Sea

H.C. Song
Marine Physical Laboratory
Scripps Institution of oceanography
La Jolla, CA 92093-0238
phone: (858) 534-0954 fax: (858) 534-7641 email: hcsong@ucsd.edu

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<http://scrippsscholars.ucsd.edu/hcsong>

LONG TERM GOALS

Study the effects of ocean dynamics on acoustic propagation and underwater communication in the region of East China Sea (ECS).

OBJECTIVE

Conduct a joint shallow water acoustic experiment with KIOST (Korea Institute of Ocean Science and Technology) to study the coupling of oceanography, acoustics, and underwater communications in the ECS. Carry out measurements of the space and time environmental and channel impulse response characteristics along with satellite imagery for internal wave activities in the experimental area.

APPROACH

The ECS and surrounding area is an extremely complex region from the perspective of oceanography, hydrography, and bathymetry. In turn, the internal wave activity within this region is also extremely complex [1]. Within the ECS, there are several mechanisms for generating internal waves including: tidal forcing, forcing by the Kuroshio, Tsushima, and Yellow Sea Circular currents, upwelling induced by the intrusion of the Kuroshio across the continental shelf (mostly in the southern region near Taiwan), and freshwater discharged from Yangtze River, as illustrated in Fig. 1(a). Bathymetry is also an important factor in internal wave generation and propagation.

While the impact of acoustic field variability associated with internal waves propagating from deep to shallow water (e.g., South China Sea) has been studied extensively, the impact of internal waves in shallow water and broad shelves (e.g., Yellow Sea and ECS) and their interactions still is poorly understood.

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During August of 2008, the ONR-sponsored Transverse Acoustic Variability EXperiment (TAVEX) was carried out in shallow water (70-80 m) within the northern ECS denoted by a red box in Fig. 1(a), southwest of Jeju Island, South Korea, with major emphasis on the effects of internal waves on signal coherence along a bottom-mounted horizontal line array [1]. Separately, the Asian Seas International Acoustics EXperiment (ASIAEX) involving several countries was conducted in the spring of 2001 to understand properties of the shallow-water boundaries governing propagation and reverberation in the ECS along with geo-acoustic properties of the seabed [2-10].

On the Korean side, KIOST (Korea Institute of Ocean Science & Technology) scientists have been keen on a collaborative research effort with the US to explore and better understand the coupling of oceanography, acoustics, and underwater communications in this very dynamic region of the Western Pacific. Motivated by the common interest in the region, SIO and KIOST have agreed to collaborate on a joint research program involving a field experiment in the area of interest as a first step forward.

The overall objective is to study the coupling of oceanography, acoustics, and underwater communications in the ECS [11-12] and a joint field experiment with Korea (SAVEX15, Shallow-water Acoustic Variability Experiment 2015) is planned for May 2015 with a major emphasis on Ocean Acoustics (OA) in the southwest of Jeju Island marked by a solid circle (blue) in Fig. 1(a) and zoomed experimental area is shown in Fig. 1(b).

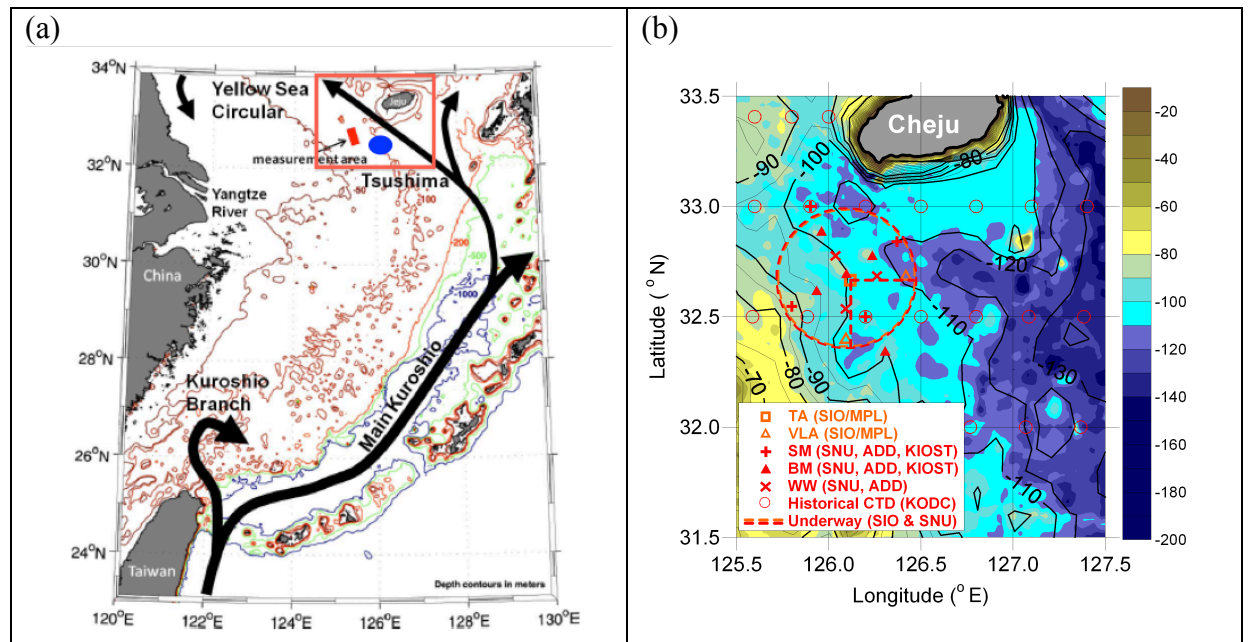


Figure 1. East China Sea (ECS) with main Kuroshio Current and its branches including Tsushima Current, along with Yellow Sea Circular Current. The SAVEX15 operational area is denoted by a solid circle (blue), while the TAVEX2008 is marked by a solid rectangular box (red). (b) General experimental area in the northern East China Sea (ECS), southwest of Jeju Island, Korea. The SAVEX15 operational area is north of 32°30'N and east of 126°5'W. Depth contours are in meters.

WORK COMPLETED

Last summer, SIO and Korean scientists participated in a joint workshop which was held in Jeju University, August 27-28, 2014. More than 30 scientists attended the workshop to present various research ideas associated with SAVEX15 and to discuss a preliminary experimental plan, including acoustic [13-14] and oceanographic equipment to be deployed.

As a preparation for SAVEX15, we also have analyzed the historical hydrographic data collected in YECS (Yellow and East China Sea) over the last 50 years from 1962 to 2011 and investigated the characteristics of the NLIWs (nonlinear internal waves) propagating under different stratifications in the southern Yellow and northern ECS with a few existing theories.

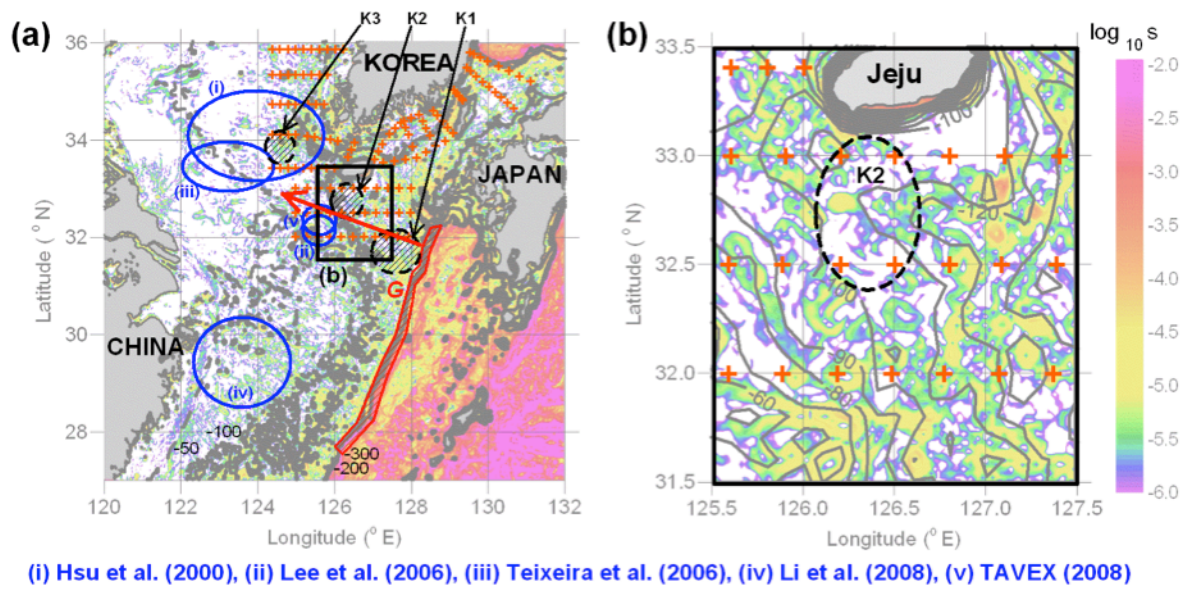


Figure 2. Bathymetry (contour) and bottom slope (color) in (a) southern Yellow and northern East China Sea and (b) zoomed-in region in the south of Jeju Island, Korea. Slope less than 10^{-6} is shown in white. Blue circles labeled from (i) to (v) indicate the area where previous internal wave observations were reported. While historical hydrographic stations around the Korean Peninsula are marked by orange crosses, those stations within the hatched areas denoted by black dashed lines (K1, K2, and K3) are exclusively analyzed. Potential generation sites and direction of main NLIWs propagation are marked with red lines and arrows (labeled 'G'). Note that (b) corresponds to the black box in (a).

RESULTS

The NLIWs occur ubiquitously in the stratified ocean of continental shelves and marginal seas. Nevertheless, their characteristics are not well known in many regions, especially southern Yellow and northern East China Sea (YECS), partly due to the lack of NLIW observations under a variety of stratified ocean conditions. To better understand statistical/theoretical characteristics of NLIWs in the YECS, historical hydrographic data collected in the area over 50 years from 1962 to 2011 are analyzed based on three existing theories (KdV/eKdV/BO) with a simple two-layer model and monthly mean climatology of background parameters. In particular, propagation

speed and characteristic width are evaluated and compared with previous NLIW observations in the region. For most observations on the shelf in the YECS, the mean characteristic width in August is either comparable to or 50 - 100 m longer than the theories, and the mean propagation speed in August is also similar to or 0.5 - 1.0 m/s faster. Notably, however, there is around 600-m deviation in the mean characteristic width between the theories and the observation of Hsu et al. 2000.

Three sites were selected to see spatial variability and evolution: K1 (continental shelf near continental slope in ECS at southwest of Japan), K2 (near south of Jeju island), and K3 (in Yellow sea). The number of measurement and the water depth at K1 are 76 and 128 m; at K2 are 336 and 100m; at K3 are 317 and 78m. The averaged phase speed becomes slower as they propagate toward northwest (along K1, K2, and K3), while the averaged width gets wider. Due to a small $I_r \approx 0.04$, NLIWs may not be breaking at all sites, and NLIWs in the regions have $O_r = 0.1633$ being much less than 1, so that rotational dispersion dominates over the third-order dispersion. Extinction time T is calculated 14.2 days with parameters so NLIWs might experience potential modifications like bottom topography and evolution, rotation, and dissipation processes. Nonetheless, characterizing the monthly climatology of two-layer KdV/eKdV parameters allows us to estimate how big, long waves can propagate in a certain month in the YECS.

IMPACT/APPLICATIONS

In the future, we see an opportunity to grow a collaborative program with South Korea utilizing their substantial facilities and assets, while their benefit is interaction with our ocean acoustics group and expertise.

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